

PATH ROUTE MODIFICATION METHOD  
AND SWITCHING SYSTEM USING THE SAME

FIELD OF THE INVENTION

5       The present invention relates to a network system having a label switching function or a wavelength switching function, and more particularly a method for modifying a route of either label path or wavelength path, and a switching system using the method.

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BACKGROUND OF THE INVENTION

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15       In a network configured with a plurality of switching systems each having a packet transfer function, there is a known technology that switching a packet having a label is controlled based on a packet forwarding table provided in each switching system.

20       The forwarding table includes either an input label or a combination of input port and input label each corresponding to a combination of output port and output label.

25       In the conventional method, a switching system performs packet transfer when a short and fixed-length label included in each packet coincides completely with any of the contents of such a forwarding table. This enables high speed transfer processing. Also, because each communication is mainly performed through an established connection, the method is also suitable for traffic

engineering such as load sharing.

In regard to such a label switching method, standardization has been studied and developed in Multi Protocol Label Switching (MPLS) Working Group in the Internet Engineering Task Force (IETF).

In the meantime, an optical wavelength division multiplexing (WDM) network begins to use to cope with traffic increase. In such a WDM network, a wavelength switching system has been attracting a wide attention, in which wavelength switching system is combined with WDM transmission equipment.

Such a wavelength switching system can be regarded equivalent to a label switching system by regarding a wavelength as a label. As a procedure of modifying a path route in such either label switching system or wavelength switching system, a route modification procedure specified in Constraint-based Routing Label Distribution Protocol (CR-LDP) is applicable.

However, there is a problem in this route modification procedure specified in this CR-LDP. On the way to the route modification, despite that information actually flows on only one route at a time, two labels for both a new route and an old route are required to reserve in a label switch router (LSR) being located where these old and new routes overlap.

In other words, on such location where the old route and new route overlap, it is not possible in the conventional

method to share a single label for both old and new routes.  
This results in waste of labels though it occurs temporarily  
during the modification procedure. Therefore, this route  
modification procedure specified in CR-LDP becomes  
5 ineffective in such a situation as the reservation of an  
extra label is not possible.

Generally in a label switching system, there is  
sufficient label space and no relation between labels and  
other resources. Therefore, the aforementioned problem  
10 will not cause a serious problem. However, in an optical  
wavelength switching system in which an optical wavelength  
is regarded as a label, available wavelengths are closely  
related to the system bandwidths, and regrettably the  
number of multiplexed wavelengths in an optical fiber is  
15 not sufficiently large at present. This results in a limited  
label space in an optical wavelength switching system and  
may cause a problem, which cannot be overlooked.

#### SUMMARY OF THE INVENTION

20 Accordingly it is an object of the present invention  
to provide a method for modifying either a label path route  
or a wavelength path route and switching system using the  
method. The proposed method enables to use an identical  
label in such a case (network location and situation of  
25 the path route modification) that a new route overlaps with  
an old route. Accordingly a flexible route modification  
becomes possible even in case of wavelength switching, etc.

having a substantially limited label space as well as having labels closely related to other resources.

In accordance with the present invention to solve the aforementioned problem, a packet switching system having  
5 a function of label path route modification has the following feature: The packet switching system includes a table for mapping either an input label value or a set of input label value and input port to an output port and an output label, wherein a state variable is set for either  
10 the input label value or the set of input label value and input port mapped in the table to represent either of the three states of 'not reserved', 'reserved', and 'double reserved'; and a packet switch for packet-switching packet data according to the information mapped in the table.

Also, in accordance with the present invention to  
15 solve the aforementioned problem, an optical cross-connect system having a function of wavelength path route modification has the following feature: The optical cross-connect system includes a table for mapping a set  
20 of input wavelength and input port to an output port and an output wavelength. A state variable is set for either the input wavelength or the combination of input wavelength and input port mapped in the table to represent either of the three states of 'not reserved', 'reserved', and 'double  
25 reserved'; and cross-connect equipment for converting wavelengths according to the information mapped in the table.

As an embodiment of the present invention to solve the  
aforementioned problem, there is provided a route  
modification method for modifying a label path from an old  
route to a new route in a network constituted by a plurality  
5 of packet switching systems connected by transmission lines.  
The method includes the steps of: including in a label  
request for a new route an identifier indicating an old  
route having a sharable label; forwarding the label request  
from a packet switching system located on upstream side  
10 to a packet switching system located on downstream side  
along the new route; in the packet switching system located  
on the downstream side, setting the label for the old route  
to a double reserved state in case the new route being  
requested in the label request overlaps with the old route,  
15 or reserving a new label in case the new route does not  
overlap with the old route; notifying the packet switching  
system located upstream from the packet switching system  
located downstream about the each reserved label;  
forwarding a label release request explicitly specifying  
20 the old route to the packet switching system located on  
downstream side along the old route; and in the packet  
switching system, when receiving the label release request,  
either setting the double reserved label to a reserved state  
being reserved only for the new route in case the new route  
25 overlaps with the old route, or releasing the label for  
old route in case the new route does not overlap with the  
old route.

As another embodiment of the present invention to solve the aforementioned problem, there is provided a route modification method for modifying a label path from an old route to a new route in a network constituted by a plurality of packet switching systems connected by transmission lines. The method includes the steps of: including in a label request for a new route an identifier indicating an old route having a sharable label; forwarding the label request from packet switching system located on upstream side to packet switching system located on downstream side along the new route; in the packet switching system located on downstream side, setting the label for the old route to a double reserved state in case the new route being requested in the label request overlaps with the old route, or reserving a new label in case the new route does not overlap with the old route; notifying packet switching system located upstream from packet switching system located downstream about the each reserved label; in the packet switching system located on upstream side, when receiving the reserved label, setting for an old label a release priority higher than a release priority for a new label; forwarding a label release request to packet switching system located on downstream side along the old route; and in packet switching system, when receiving the label release request, either setting the double reserved label to a reserved state being reserved only for the new route in case the new route overlaps with the old route, or

releasing the label for old route having the higher release priority in case the new route does not overlap with the old route.

Further, as an embodiment of the present invention

5 to solve the aforementioned problem in a network constituted by a plurality of optical cross-connect units connected by transmission lines, there is provided a route modification method for modifying a wavelength path from an old route to a new route. The method includes the steps

10 of: including in a wavelength request for a new route, an identifier indicating an old route having a sharable wavelength; forwarding the wavelength request from an optical cross-connect system located on upstream side to an optical cross-connect system located on downstream side

15 along the new route; in the optical cross-connect system located on downstream side, setting the wavelength for the old route to a double reserved state in case the new route being requested in the wavelength request overlaps with the old route, or reserving a new wavelength in case the

20 new route does not overlap with the old route; notifying the optical cross-connect system located upstream from the optical cross-connect system located downstream about the each reserved wavelength; forwarding a wavelength release request explicitly specifying the old route to the optical

25 cross-connect system located on downstream side along the old route; and in the optical cross-connect system, when receiving the wavelength release request, either setting

the double reserved wavelength to a reserved state being reserved only for the new route in case the new route overlaps with the old route, or releasing the wavelength for old route in case the new route does not overlap with the old route.

Still further, as another embodiment of the present invention to solve the aforementioned problem in a network constituted by a plurality of optical cross-connect units connected by transmission lines, there is provided a route modification method for modifying a wavelength path from an old route to a new route. The method includes the steps of: including in a wavelength request for a new route an identifier indicating an old route having a sharable wavelength; forwarding the wavelength request from an optical cross-connect system located on upstream side to an optical cross-connect system located on downstream side along the new route; in the optical cross-connect located on downstream side, setting the wavelength for the old route to a double reserved state in case the new route being requested in the wavelength request overlaps with the old route, or reserving a new wavelength in case the new route does not overlap with the old route; notifying the optical cross-connect system located upstream from the optical cross-connect system located downstream about the each reserved wavelength; in the optical cross-connect located on upstream side, when receiving the reserved wavelength, setting for an old wavelength a release priority higher



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than a release priority for a new wavelength; forwarding  
a wavelength release request to the optical cross-connect  
system located on downstream side along the old route; and  
in the optical cross-connect system, when receiving the  
5 wavelength release request, either setting the double  
reserved wavelength to a reserved state being reserved only  
for the new route in case the new route overlaps with the  
old route, or releasing the wavelength for old route having  
the higher release priority in case the new route does not  
10 overlap with the old route.

Further scopes and features of the present invention  
will become more apparent by the following description of  
the embodiments with the accompanied drawings.

15 BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows an example of a network configuration  
constituted by label switching systems each functioning  
as switch equipment.

20 FIGS. 2A to 2E show diagrams, each illustrating a  
management table.

FIG. 3 shows a diagram illustrating a process of  
forwarding a label request message.

FIG. 4 shows a diagram illustrating a process of  
notifying a reserved label using a label mapping message.

25 FIG. 5 shows a diagram illustrating a process of issuing  
a label release message.

FIG. 6 shows a diagram illustrating a process of sending

a label request message in the first embodiment.

FIG. 7 shows a diagram illustrating a process of notifying a reserved label using a label mapping message in the first embodiment.

5        FIG. 8 shows a diagram illustrating a process of issuing a label release message in the first embodiment.

FIG. 9 shows an example of a system configuration in which label switching system is applied to packet switching system.

10        FIGS. 10A and 10B show examples of label management table contents in the configuration using packet switching system.

15        FIGS. 11A to 11E show diagrams, each illustrating the contents of the label management table when route I is established in the first embodiment of the configuration example using the packet switching system shown in FIG 9.

20        FIG. 12 shows a diagram illustrating a process of sending a label request message in the first embodiment of the configuration example using the packet switching system shown in FIG 9.

FIG. 13 shows a diagram illustrating a process of notifying a reserved label using a label mapping message in the first embodiment of the configuration example using the packet switching system shown in FIG 9.

25        FIG. 14 shows a diagram illustrating a process of issuing a label release message in the first embodiment of the configuration example using the packet switching

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FOOTNOTES

system shown in FIG 9.

FIGs. 15A to 15E show diagrams, each illustrating contents of the label management table when route I is established in the second embodiment of the configuration example using the packet switching system shown in FIG 9.

FIG. 16 shows a diagram illustrating a process of sending a label request message in the second embodiment of the configuration example using the packet switching system shown in FIG 9.

FIG. 17 shows a diagram illustrating a process of notifying a reserved label using a label mapping message in the second embodiment of the configuration example using the packet switching system shown in FIG 9.

FIG. 18 shows a diagram illustrating a process of issuing a label release message in the second embodiment of the configuration example using the packet switching system shown in FIG 9.

FIG. 19 shows an example of a system configuration in which a label switching is applied to an optical cross-connect.

FIG. 20 shows an example of the contents of a wavelength management table in the configuration example using the optical cross-connect shown in FIG. 19.

FIG. 21 shows a network configuration example using the optical cross-connect shown in FIG 19.

FIGs. 22A to 22E show diagrams, each illustrating contents of the wavelength management table when route I

is established in the first embodiment of the configuration example using the optical cross-connect shown in FIG 19.

FIG. 23 shows a diagram illustrating a process of  
5 sending a wavelength request message in the first embodiment of the configuration example using the optical cross-connect shown in FIG 19.

FIG. 24 shows a diagram illustrating a process of  
10 notifying a reserved wavelength using a wavelength notification message in the first embodiment of the configuration example using the optical cross-connect shown in FIG 19.

FIG. 25 shows a diagram illustrating a process of  
15 issuing a wavelength release message in the first embodiment of the configuration example using the optical cross-connect shown in FIG 19.

FIGS. 26 show diagrams, each illustrating contents  
of the wavelength management table when route I is established in the second embodiment of the configuration  
20 example using the optical cross-connect shown in FIG 19.

FIG. 27 shows a diagram illustrating a process of  
sending a wavelength request message in the second embodiment of the configuration example using the optical cross-connect shown in FIG 19.

FIG. 28 shows a diagram illustrating a process of  
25 notifying a reserved wavelength using a wavelength notification message in the second embodiment of the

configuration example using the optical cross-connect shown in FIG 19.

FIG. 29 shows a diagram illustrating a process of issuing a wavelength release message in the second embodiment of the configuration example using the optical cross-connect shown in FIG 19.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments of the present invention are described hereinafter referring to the charts and drawings, wherein like numerals or symbols refer to like parts.

For the sake of easier understanding of the present invention, the aforementioned conventional route modification method in switching system is explained prior to the description of the present invention.

FIG. 1 shows an example of a network configuration, which includes five (5) label switching routers (LSR) as switching systems.

In FIG. 1, a plurality of label switching systems are connected using a physical transmission medium such as an optical fiber and coaxial line: between LSR1 and LSR2, LSR2 and LSR3, LSR 3 and LSR4, LSR4 and LSR5, and moreover between LSR2 and LSR4.

In the initial state, as shown with a fine dotted line in FIG. 1, there has been established a label switching path (LSP) I having a route from LSR1 to LSR5 through LSR2,

LSR3 and LSR4.

Here, each of label switching systems LSR1, LSR2, LSR3, LSR4 and LSR5 has the own management table A, B, C, D or E shown in FIGs. 2A to 2E.

5 Each management table A to E includes data for transmitting information along route I through LSR1, LSR2, LSR3, LSR4 and LSR5, including corresponding input information, an LSPID for identifying label switching path, input and output ports, and input and output label.

10 Information being transmitted along the label switching path of route I is forwarded to LSR2 after label L21 is added in LSR1. In LSR2, label L21 is replaced by label L31 to forward to LSR3.

LSR3 replaces label L31 by label L41 to forward to  
15 LSR4, and LSR4 replaces label L41 by label L51 to forward to LSR5. LSR5 then deletes the label. Thus the information is transmitted from LSR1 to LSR5.

Now, there is assumed a case that the label switching path of route I is to be modified to another label switching  
20 path of route II passing through LSR1 - LSR2 - LSR4 - LSR5.

In this case, as a first step, LSR1 located at the entry point of the label switching path of route II forwards a Label Request Message along new route II to LSR2 located downstream next to LSR1.

25 LSR1 then waits for a Label Mapping Message corresponding to the Label Request Message to be transmitted from LSR2. The state at this time is described

hereafter corresponding to varied contents of each table shown in FIG. 3.

In FIG. 3, when LSR2 receives the aforementioned Label Request Message from LSR1 (procedure p2), LSR2 reserves  
5 a new label L22 for new route II (FIG. 3B).

At this time, LSR2 defers transmitting a Label Mapping Message back to LSR1 until an output label corresponding to label L22 is fixed.

In order to obtain the output label corresponding to  
10 label L22, LSR2 further forwards a Label Request Message to the next LSR4 located downstream (procedure P3). LSR4 also reserves a new label L42 for the new route (FIG. 3C).

LSR4 defers transmitting a Label Mapping Message back to LSR2 until an output label corresponding to label L42  
15 is fixed.

Next, in order to obtain the output label corresponding to label L42, LSR4 further forwards a Label Request Message to the next LSR5 located downstream (procedure P4). LSR5 also reserves a new label L52 for new route II.

20 Thus new route II is fixed, and therefore as a next step the reserved label is notified using a Label Mapping Message. This situation is explained hereafter referring to FIG. 4. LSR5 notifies LSR4, located upstream immediately before LSR5, of the reserved label for new route II using  
25 a Label Mapping Message (procedure P5).

Successively from the label switching system located downstream, each output label corresponding to each input

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label is fixed. That is, LSR4 notifies LSR2 of label L42, and LSR2 notifies LSR1 of label L22, indicating that each new label has been reserved for new route II using each Label Mapping Message (procedures P6, P7 and P8).

5       Accordingly, a path is fixed for new route II. LSR1 then changes the route for transmitting information from old route I to new route II (procedure P8).

Thus old route I becomes unnecessary. As the third step, therefore, LSR1 issues a Label Release Message  
10 specifying old label L21 (procedure P9). This situation is described hereafter referring to FIG. 5.

On receipt of the aforementioned Label Release Message, LSR2 forwards a Label Release Message to LSR3 specifying output label L31 corresponding to label L21, and then  
15 releases label L21 (procedure P10).

Successively, LSR3 and LSR4 perform the similar processing (procedures P11, P12). When LSR5 releases label L51, release of old route I is completed (procedure P13).

As mentioned above, according to the conventional  
20 method, two labels are reserved in the midst of route modification procedure at each LSR in which new route II overlaps with old route I, despite that at any time actual information flows on only a single route.

For example, in the case of LSR2 shown in FIG. 3, label  
25 L21 is reserved data flow route I. In addition, for new route II initiated by the Label Request Message, the new label L22 is reserved. Thus two labels are reserved at this



stage. This state continues until the Label Release Message against label L21 for old route I is received (refer to FIG. 5B).

Accordingly, the present invention is aimed to solve the problem of such duplicated registration of labels reserved for an old route and a new route instead of sharing a single label. To explain the present invention comprehensively, in the conventional method, label sharing is not possible between an old route and a new route. This is because LSR managing each label cannot identify a state of one label being reserved for a plurality of routes in the conventional method.

In order to solve the above-mentioned problem, according to the present invention, there are introduced, in each LSR, state variables enabling to maintain the three states of; 'not reserved', 'reserved' and 'doubly reserved', corresponding to each input label.

This makes it possible to recognize a path to be double reserved temporarily in the midst of route modification. The outline of this procedure is explained hereafter referring to FIGS. 6 to 8. Now, in a network shown in FIG. 1, it is assumed that there is route I from LSR1 to LSR5 through LSR2, LSR3 and LSR4, and that route modification is to be performed from route I to route II which is originated from LSR1 to LSR5 through LSR2 and LSR4.

Here, note that a forwarding table to be used for actual information forwarding may be implemented separately from

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management tables, respectively shown in FIGs. 2A to 2E, or otherwise may be implemented combined with the management table into one table form.

When performing the aforementioned route modification, as a first step, a message requesting a label, for example a Label Request Message specified in CR-LDP is forwarded along the new route toward LSR located downstream.

In the label request message, there is included a path identifier indicating the route to be modified using, for example, LSPID of TLV (type-level-value) parameters in CR-LDP, in addition to information related to the new route. This situation is explained referring to FIG. 6.

In LSR of which the input port for new route II is identical to the input port for old route I, such as LSR2, when the Label Request Message which requests a label is received (procedure P2), the LSR doubly reserves the label having been in use for old route I (as shown with © in FIG. 6B), and then forwards a Label Request Message to the next LSR4 located downstream to request a label (procedure P3).

In other LSR, such as LSR4 in which the input port for new route II is not identical to the input port for old route I (including LSR which old route I does not pass through), the LSR reserves a new label. The LSR then forwards a Label Request Message requesting a label to the next LSR5 located downstream (procedure P3).

In such a manner, Label Request Messages are

transferred on new route II successively from the upstream side to the downstream side. When the message reaches LSR5 being located at the exit of new route II (procedure P4), LSR5 reserves a label according to the received label request, and then notifies the previous LSR4 being located upstream of this reserved label along new route II. This label notification is performed using, for example, a Label Mapping Message specified in CR-LDP.

This Label Mapping Message includes an identifier denoting the path to which this label belongs, and a label value for this route which has been reserved in the originator of the message. This situation is illustrated in FIG. 7. On receipt of the message, LSR4 stores the contents in the message into an internal management table, and then forwards a Label Mapping Message to notify the previous LSR2 being located upstream of the reserved label.

When this message reaches LSR1 being located at the entry point of the new route, new route II is established.

Thus old route I becomes no more necessary. Therefore LSR1 forwards a message along old route I to request to release the label of old route I to the next LSR2 being located downstream. For this purpose, for example a Label Release Message specified in CR-LDP is used.

This situation is shown in FIG. 8. This Label Release Message includes the path identifier to be deleted. On receipt of this message, the LSR, in which the label being indicated to release is a doubly reserved label, for example

LSR2, changes the state of the label being reserved only for new route II now. Meanwhile, the other LSR in which the label being indicated to release is reserved only for old route I, for example LSR4, changes the state of the label being not reserved now.

Next, embodiments of the present invention are described hereafter giving more concrete examples.

In FIG. 9, there is shown a configuration example in which label switching system is applied to packet switching system, as a second embodiment of the present invention. The packet switching system shown in FIG. 9 includes a packet switch 1, a plurality of input interfaces IIF1 to IIFN being connected to the input side of packet switch 1, and a plurality of output interfaces OIF1 to OIFN. Also packet switching system includes a controller 2.

Controller 2 has a label management table 3. Each plurality of input interfaces IIF1 to IIFN has a forwarding table 4.

This forwarding table 4 is set by controller 2 shown in FIG. 9. In label management table 3 provided in controller 2, information sets related to the label to which a procedure is being executed for either establishing a path or modifying a route, as well as label information for use in packet forwarding.

In this label management table 3, there is provided a state variable for either each input label or each combination of input label and input port number,

indicating one of the three states of 'not reserved', 'reserved' and 'double reserved'. In FIGs. 10A and 10B, an example of the contents of label management table 3 is shown.

5 In FIGs. 10A and 10B, an indicator 'X' denotes 'not reserved', '○' denotes 'reserved', and '◎' denotes 'double reserved'. Management table 3 shown in FIG. 10A indicates a case in which a combination of an input label value and an input port number is mapped to an output port number and an output label. Meanwhile, management table 10 3 shown in FIG. 10B indicates another case that an output port number and an output label are mapped against an input label value.

Now, a route modification procedure is described 15 hereafter taking a specific example. A network similar to that shown in FIG. 1 is also assumed in the following description. Namely, the network includes five label switching systems LSR1 to LSR5 each constituted by a label switch router (LSR).

20 Label switching systems (or simply referred to as LSR) are connected using a transmission medium such as an optical fiber. There are connections between LSR1 and LSR2, between LSR2 and LSR3, between LSR 3, LSR4, between LSR4 and LSR5, and between LSR2 and LSR4.

25 It is assumed in such a network that there has been established a label switching path (LSP) constituting route I being originated from LSR1 and terminated by LSR5, in

order of LSR1 - LSR2 - LSR3 - LSR4 - LSR5. The contents of label management table 3 at that time is as shown in FIGs. 11A to 11E.

Now hereafter a case is explained that, in these label switching systems, the route is to be modified from  
5   aforementioned route I to a route passing through LSR1 - LSR2 - LSR4 - LSR5. As a first step, as shown in FIG. 12, a label request message is forwarded to the label switching systems along new route II from LSR located at the entry  
10   point of route I.

Namely, LSR1 located at the entry of route II forwards a message requesting a label for route II along new route II using, for example, Label Request Message specified in CR-LDP to the next LSR2 located downstream.

15   Such a message requesting a label includes route information, which indicates new route II, and a path identifier, which indicates the path to be modified.

On receipt of this label request message, LSR2 recognizes from the received path identifier that old route  
20   I corresponding to this path has the identical input port to that receiving the message. Therefore LSR2 reserves the label L21 again which is the identical value of the input label for old route I (as shown with © in FIG. 12B).

The notification of the reserved label value of L21  
25   to LSR1 is deferred until an output label for new route II is reported from the downstream side. Also, LSR2 recognizes from the received route information that new

route II will pass through port 3 to LSR4.

LSR2 then forwards a message requesting a label using, for example, Label Request Message specified in CR-LDP to LSR4 so as to obtain an output label for new route II.

5       On receipt of this message, LSR4 recognizes from the received path identifier that the path for the old route I uses a port different from the port on which the message was received.

LSR4 then reserves a new label L42 for new route II.  
10       However, the notification of the reserved label value of L42 to LSR2 is deferred until an output label for new route II is reported from the downstream side. Also, LSR4 recognizes from the received route information that new route II is to be extended to LSR5 through port 1.

15       On receipt of this message, LSR5 recognizes from the received path identifier that the path for old route I uses the identical input port on which the message was received. Therefore LSR5 reserves the label L51 again which is the identical value of the input label for old route I (as shown  
20       with © in FIG. 12E).

Now route II is fixed and the procedure proceeds to the second step shown in FIG. 13. In the second step, the reserved label is notified from LSR5 located at the exit point back to the other label switching systems LSR along  
25       new route II. As a message for notifying the label, for example, a Label Mapping Message specified in CR-LDP is used. Namely, LSR5 notifies LSR4, located upstream previous

to LSR5, of the reserved label L51 for new route II using, for example, a Label Mapping Message (procedure P6).

This message includes a path identifier and a label value for notification. On receipt of this message, LSR4  
5 stores the label value L51 into the table entry corresponding to new route II in management table 3.

Thus entire contents of management table 3 become to have effective values, and the contents are reflected to forwarding table 4. Also, LSR4 notifies LSR2 of the label  
10 value L42 having been reserved for new route II. LSR2 then performs the similar processing as LSR4.

LSR1 stores the received label value into management table 3. The procedure then proceeds to the third step shown in FIG. 14.

15 In the third step, first LSR1 located at the entry forwards along old route I, to next LSR2 being located downstream, a message for requesting LSR2 to release the label for old route I.

This release request message includes the path  
20 identifier and path information related to old route I. On receipt of this message, LSR2 recognizes from the received path identifier that to release label L21 is requested. Accordingly, LSR2 releases label L21 and modifies the condition of 'double reserved' to simple  
25 'reserved'.

Also, LSR2 deletes the output label information related to old route I and forwards a message requesting



the release of label L31 to LSR3. LSR3 then determines from the path identifier the request is to release label L31, and modifies the condition of label L31 to 'not reserved' state and deletes the output label information  
 5 (as shown with X in FIG. 14C).

LSR3 also forwards a message to LSR4 requesting to release label L41. LSR4 determines from the path identifier and the route information that the request is to release label L41, to modify the condition of label L41 to 'not  
 10 reserved' state and deletes the output label information.

Further, LSR4 forwards to LSR5 a message requesting to release label L51. LSR5 determines from the path identifier that the request is to release label L51, and modifies the condition of label L51 from 'double reserved'  
 15 state to 'reserved' state (as shown with O in FIG. 14E). As a result of these procedures, new route II is established and old route I is released.

Next, hereafter another embodiment of the present invention is explained. A network configuration, a route  
 20 on label switching systems having been set previously, and a new route are identical to these in the above-mentioned embodiment. The contents of label management table 3 before route modification is also assumed as shown in FIGs. 15A to 15E.

25 In this embodiment, only one point different from the aforementioned embodiment is that a release priority is newly added. A situation in the first step is shown in FIG.

16. As described above, the contents of label management table are the same as those of label management table shown in FIG. 12 except that release priority is added in FIG 16. The release priority values are not varied in the  
5 processing of messages which request labels for route II.

A situation in the second step is shown in FIG. 17. When label information for new route II is received from the downstream side, the release priority of the label for  
10 old route I is changed to a higher value than the release priority of the label for new route II. Other procedure is identical to that of the former embodiment.

A situation in the third step is shown in FIG. 18. In the third step, first LSR1 located at the entry point  
15 forwards a label release message to the next LSR2 located downstream along old route I, requesting to release the label corresponding to old route I.

The label release message includes a path identifier. On receipt of this message, LSR2 recognizes, from the path  
20 identifier and the release priority that a label release request is to be forwarded to LSR3.

Also, when recognizing from the path identifier that the request is to release label L21, LSR2 releases label L21 and then changes the condition of label L21 from 'double  
25 reserved' to 'reserved' indicating the reservation for only the new route (as shown in the priority field and with a reservation mark ○ in FIG. 18B). Further, determining from

the release priority, LSR2 deletes output label information for old route I, and then forwards a label release message to LSR3 requesting to release the label for old route I.

5 LSR3 determines the request is to release label L31 because there is only one entry corresponding to path identifier '1'. LSR3 also determines that a release request message to be forwarded next is to LSR4. LSR3 changes the condition of label L31 to 'not reserved' and deletes the  
10 output label information.

LSR3 then forwards a label release request to LSR4. LSR4 determines from the path identifier and the release priority that the request is to release label L41 and also a release request message is to be forwarded to LSR5. LSR4  
15 then changes the condition of label L41 to 'not reserved' and deletes the output label information.

LSR4 also forwards a label release message to LSR5. LSR5 determines from the path identifier, that the request is to release label L51 and changes the condition of label  
20 L51 from 'double reserved' to 'reserved'.

Thus through the above-mentioned procedure new route II is established and old route I is released.

Now, a third embodiment is explained hereafter. In FIG. 19, there is shown an optical cross-connect as a  
25 configuration example of label switching system in the third embodiment. As a main portion of the optical cross-connect, an optical switch 5 is provided, as well

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as a controller 6 for controlling optical switch 5. There are also provided a wavelength demultiplexer 7 on the input side of optical switch 5, and a wavelength converter 8 and a wavelength multiplexer 9 on the output side of optical switch 5.

In each plurality of input ports, optical wavelength multiplexed signal is demultiplexed into wavelength  $\lambda_1$  to  $\lambda_n$ , to space-switch in optical switch 5. The signal is then wavelength-converted in wavelength converter 8 and wavelength-multiplexed in wavelength multiplexer 9 to output.

In optical switch 5, a path is established by controller 6. In controller 6, there is provided a wavelength management table 60 for managing information related to a wavelength for performing a procedure for path establishment and path route modification, in addition to wavelengths for use in wavelength path forwarding.

In this wavelength management table 60, a state variable is applied to each combination of input wavelength and input port number, indicating one of the three states of 'not reserved', 'reserved' and 'double reserved'.

In FIG. 20, an example of wavelength management table 60 is shown, in which an indicator 'X' denotes 'not reserved', '○' denotes 'reserved', and '◎' denotes 'double reserved'.

Now, hereafter there is explained the route modification on optical cross-connect shown in FIG. 19 for

use in the optical network. The network is constituted by five (5) optical cross-connects (OXC) as shown in FIG 19. Using optical transmission media or the like, physical connections are made between OXC1 and OXC2, OXC2 and OXC3, 5 OXC3 and OXC4, OXC4 and OXC5, and also between OXC2 and OXC4.

It is assumed in such a network that there has been established a wavelength path constituting route I being originated from OXC1 and terminated by OXC5, in order of 10 OXC1 - OXC2 - OXC3 - OXC4 - OXC5. The contents of wavelength management table 3 at that time are as shown in FIGS. 22A to 22E.

Now hereafter a case is explained that, in these optical cross-connects, the route is to be modified from 15 aforementioned route I to a route II passing through OXC1 - OXC2 - OXC4 - OXC5. As a first step, as shown in FIG. 23, a wavelength request message is forwarded to the optical cross-connects along new route II from OXC located at the entry point of route I.

20 Namely, OXC1 located at the entry of the wavelength path forwards a message requesting a wavelength for route II to the next OXC2 located downstream along new route II. This message requesting a wavelength includes route information which indicates new route II, and a path 25 identifier which indicates the wavelength path to be modified.

On receipt of this wavelength request message, OXC2

recognizes from the received path identifier that old route I corresponding to this path has the identical input port to that receiving the message. Therefore OXC2 reserves the wavelength  $\lambda_{21}$  again which is the identical value of  
5 the input wavelength for old route I (as shown with © in FIG. 23B).

The notification of the reserved wavelength value of  $\lambda_{21}$  to OXC1 is deferred until an output wavelength for new route II is reported from the downstream side. Also,  
10 OXC2 recognizes from the received route information that new route II will pass through port 3 to OXC4. OXC2 then forwards a message requesting a wavelength to OXC4 so as to obtain an output wavelength for new route II.

On receipt of this message, OXC4 recognizes from the  
15 received path identifier that the path for the old route I uses a different port from the port on which the message was received. OXC4 therefore reserves a new wavelength  $\lambda_{42}$  for new route II. However, the notification of the reserved wavelength value of  $\lambda_{42}$  to OXC2 is deferred until  
20 an output wavelength for new route II is reported from the downstream side.

Also, OXC4 recognizes from the received route information that new route II is to be extended to OXC5 through port 1. OXC4 then forwards a wavelength request  
25 message to OXC5 so as to obtain an output wavelength for new route II.

On receipt of this message, OXC5 recognizes from the

received path identifier that the path for old route I  
uses the identical input port on which the message was  
received. Therefore OXC5 reserves the wavelength  $\lambda 51$  again  
which is the identical value of the input wavelength for  
5 old route I.

Now route II is fixed and the procedure proceeds to  
the second step shown in FIG. 24. In the second step, OXC5  
located at the exit point transmits to OXC4 being located  
upstream a wavelength notification message indicating  
10 wavelength  $\lambda 51$  has been reserved for new route II.

This wavelength notification message includes a path  
identifier and a wavelength value for notification. On  
receipt of this message, OXC4 stores the wavelength value  
 $\lambda 51$  into a table entry corresponding to the path identifier  
15 of new route II in wavelength management table 60. Thus  
entire contents of wavelength management table 60 become  
to have effective values, and the contents are reflected  
to the optical switch.

Also, OXC4 notifies OXC2 of the wavelength value having  
20 been reserved for new route II. OXC2 then performs the  
similar processing as OXC4. OXC1 stores the received  
wavelength value into management table 60 and replaces  
input information to reflect to the optical switch. The  
procedure then proceeds to the third step shown in FIG.  
25 25.

In the third step, as shown in FIG. 25, first OXC1  
located at the entry of the wavelength path forwards a

wavelength release message along old route I to next OXC2 being located downstream, requesting OXC2 to release the wavelength for old route I (procedure P9).

This release request message includes the path  
5 identifier and path information related to old route I. On receipt of this message, OXC2 recognizes from the received path identifier that to release wavelength  $\lambda$  21 is requested. Accordingly OXC2 releases wavelength  $\lambda$  21 and modifies the condition from 'double reserved' to  
10 'reserved' (procedure P10).

Also, OXC2 deletes the output wavelength information related to old route I and forwards a wavelength release request to OXC3. OXC3 then determines from the path identifier the request is to release wavelength  $\lambda$  31. OXC3  
15 then modifies the condition of wavelength  $\lambda$  31 to 'not reserved' state and deletes the output wavelength information. OXC3 also forwards a message to OXC4 requesting to release wavelength  $\lambda$  41.

OXC4 determines from the path identifier and the route  
20 information that the request is to release wavelength  $\lambda$  41. OXC4 then modifies the condition of wavelength  $\lambda$  41 to 'not reserved' state and deletes the output wavelength information (procedure P11). Further, OXC4 forwards a wavelength release message to OXC5.

25 OXC5 determines from the path identifier that the request is to release wavelength  $\lambda$  51, and modifies the condition of wavelength  $\lambda$  51 from 'double reserved' state



to 'reserved' state. As a result of these procedures, new route II is established and old route I is released.

Next, another embodiment of the present invention is explained hereafter.

5 It is assumed that a network configuration, a route on the optical cross-connects having been set previously, and a new route are identical to these in the above-mentioned embodiment.

Also, the contents of wavelength management table 60  
10 before route modification is performed is assumed as shown in FIGs. 26A to 26E.

Compared to the embodiment shown in FIG. 22, only one point that a release priority is newly added is different. A situation in the first step is shown in FIG. 27. As  
15 described above, the contents of wavelength management table are the same as those shown in FIG. 22 except that release priority is added in FIG 26. The release priority values are not varied here.

A situation in the second step is shown in FIG. 28.  
20 When wavelength information for new route II is received from the downstream side, the release priority of the wavelength for old route I is changed to a higher value than the release priority of the wavelength for new route II. Other procedure is identical to that of the former  
25 embodiment.

A situation in the third step is shown in FIG. 29. In the third step, first, OXC1 located at the entry point

forwards a wavelength release message to the next OXC2 located downstream along old route I, requesting to release the wavelength corresponding to old route I (procedure P9).

The wavelength release message includes a path identifier. On receipt of this message, OXC2 recognizes, from the path identifier and the release priority, that a wavelength release message is further to be forwarded to OXC3.

Also, OXC2 recognizes from the path identifier that the request is to release wavelength  $\lambda_{21}$ . OXC2 thus releases wavelength  $\lambda_{21}$  and then changes the condition of wavelength  $\lambda_{21}$  from 'double reserved' to 'reserved'. Further, determining from the release priority, OXC2 deletes output wavelength information for old route I, and then forwards a wavelength release message to OXC3 requesting to release the wavelength for old route I (procedure P10).

OXC3 determines the request is to release wavelength  $\lambda_{31}$  because there is only one entry corresponding to path identifier '1'. OXC3 also determines that a release request message is to be forwarded to OXC4. OXC3 changes the condition of wavelength  $\lambda_{31}$  to 'not reserved' and deletes the output wavelength information. OXC3 also forwards a wavelength release message to OXC4 (procedure P11).

OXC4 determines from the path identifier and the release priority that the request is to release wavelength  $\lambda_{41}$ , and that a release request message is to be forwarded

to OXC5. OXC4 then changes the condition of wavelength  $\lambda 41$  to 'not reserved' and deletes the output wavelength information. OXC4 also forwards a wavelength release message to OXC5 (procedure P12).

- 5 OXC5 then determines from the path identifier that the request is to release wavelength  $\lambda 51$ , to changes the condition of wavelength  $\lambda 51$  from 'double reserved' to 'reserved' (procedure P13).

Through the above-mentioned procedures, new route II  
10 is established and old route I is released. The method and the system according to the present invention enables to prevent duplicated label setting in the route modification performed in the network.

The foregoing description of the embodiments is not  
15 intended to limit the invention to the particular details of the examples illustrated. For example, the above description is based on a network configuration constituted by five switching systems. However, the present invention is not limited to this configuration. Any suitable  
20 modification and equivalents may be resorted to the scope of the invention. All features and advantages of the invention which fall within the scope of the invention are covered by the appended claims.